Insights on TTL dehydration mechanisms from microphysical modelling of aircraft observations

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The Tropical Tropopause Layer (TTL), a transition layer between the upper troposphere and lower stratosphere in the tropics, serves as the entryway of various trace gases into the stratosphere. Of particular interest is the transport of water vapor through the TTL, as WV is an important greenhouse gas and also plays a significant role in stratospheric chemistry by affecting polar stratospheric cloud formation and the ozone budget. While the dominant control of stratospheric water vapor by tropical cold point temperatures via the “freeze-drying” process is generally well understood, the details of the TTL dehydration mechanisms, including the relative roles of deep convection, atmospheric waves and cloud microphysical processes, remain an active area of research.

The dynamical and microphysical processes that influence TTL water vapor concentrations are investigated in simulations of cloud formation and dehydration along air parcel trajectories. We first confirm the validity of our Lagrangian models in a case study involving measurements from the Airborne Tropical TRopopause EXperiment (ATTREX) flights over the central and eastern tropical Pacific in Oct-Nov 2011 and Jan-Feb 2013. ERA-Interim winds and seasonal mean heating rates from Yang et al. (2010) are used to advance parcels back in time from the flight tracks, and time-varying vertical profiles of water vapor along the diabatic trajectories are calculated in a one-dimensional cloud model as in Jensen and Pfister (2004) but with more reliable temperature field, wave and convection schemes. The simulated water vapor profiles demonstrate a significant improvement over estimates based on the Lagrangian Dry Point, agreeing well with aircraft observations when the effects of cloud microphysics, subgrid-scale gravity waves and convection are included. Following this approach, we examine the dynamical and microphysical control of TTL water vapor in the 30ºS-30ºN latitudinal belt and elucidate the dominant processes in the winter and summer seasons. Implications of the TTL dehydration processes for the regulation of global stratospheric humidity will be discussed.